Metal abundance evolution in distant galaxy clusters

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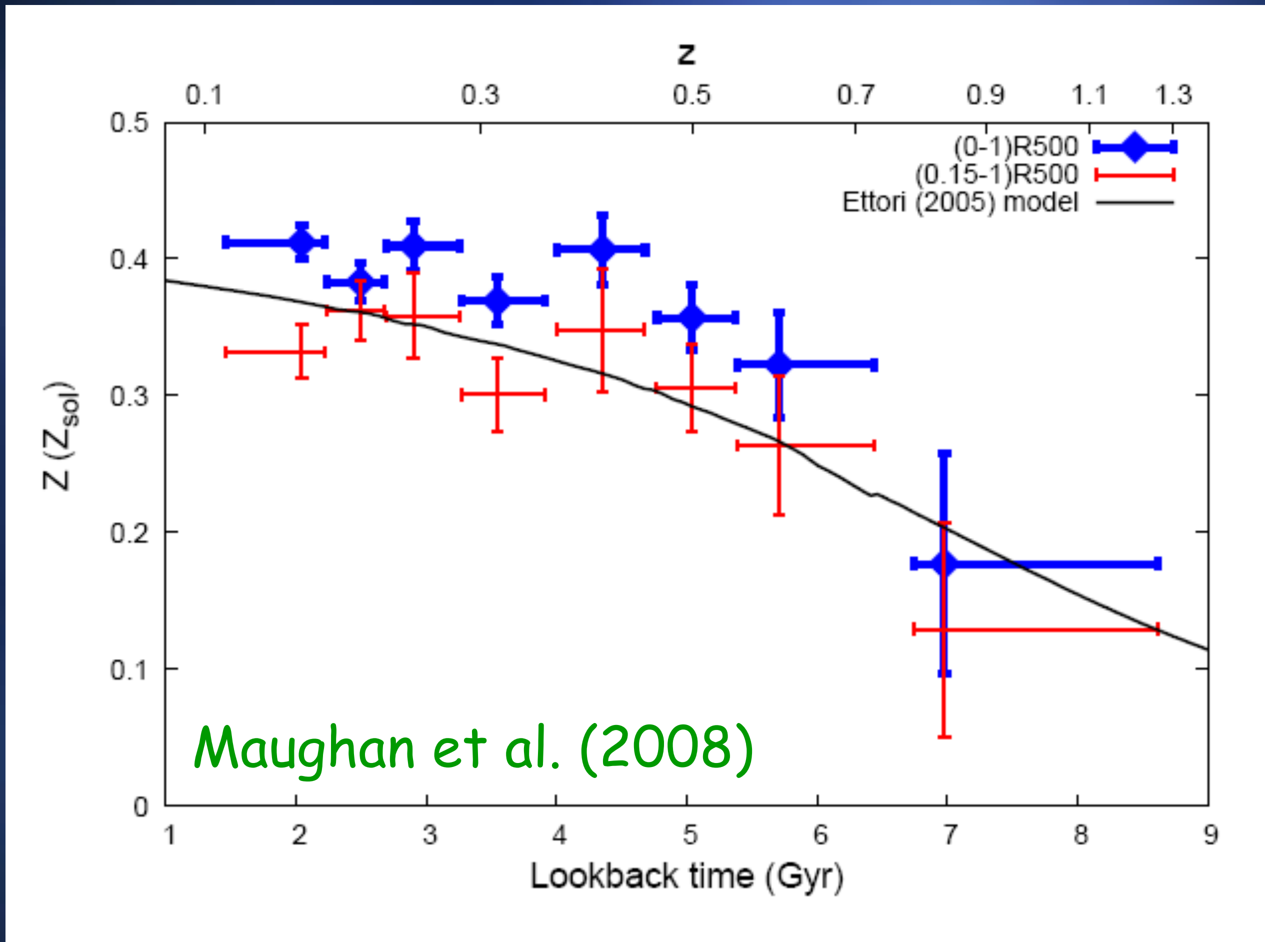
Measures of metal content at high z

- Balestra et al. (2007) obtained single emission-weighted estimates of 56 clusters (at $0.3 < z < 1.3$) from Chandra and XMM-Newton

- Measuring Fe abundance within (0.15–0.3) R_{vir} they found a negative evolution of Z(Fe) with z:
  - $Z(Fe) \approx 0.4\ Z_{\odot}$ at $0.3 \leq z \leq 0.5$
  - $Z(Fe) \approx 0.25\ Z_{\odot}$ at $z \geq 0.5$

- This result has been confirmed by Maughan et al. (2008) on a sample of 116 Chandra clusters at $0.1 < z < 1.3$, where Z drop by 50% between $z=0.1$ and $z \approx 1$

Measures of metal content at high z



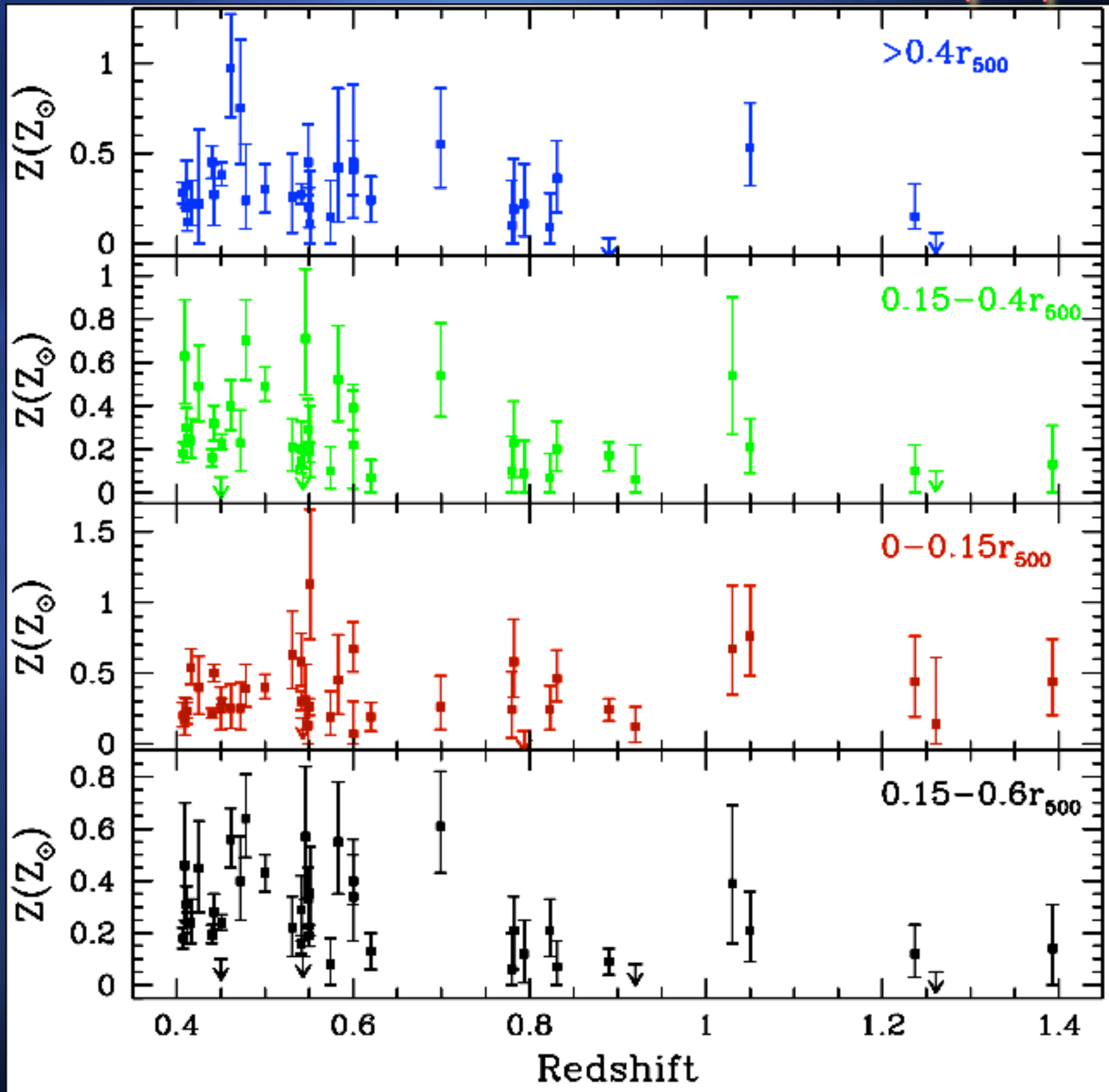
- This evolution is not simply driven by the appearance or disappearance of the cool cores

XMM-Newton high redshift cluster sample

- We selected a sample of 40 galaxy clusters at $0.4 < z < 1.4$ from the XMM-Newton archive.
- Taking advantage of EPIC XMM-Newton high throughput and effective area, we performed a spatially resolved spectral analysis of the clusters in the sample.
- The aim of this work is to determine if the decrease of Z with redshift observed by Balestra et al. & Maughan et al. is due entirely to physical processes associated with the production and release of Fe into the ICM, or partially associated with a redistribution of metals connected to the evolution of cool cores.

Spectral analysis results

Baldi et al. 2010 in prep.



- Each cluster was analyzed in 3 spatial bins, extracting spectra and fitting an XSPEC *mekal* model at:
  - $r < 0.15\ r_{500}$
  - $0.15\ r_{500} < r < 0.4\ r_{500}$
  - $r > 0.4\ r_{500}$

Spectral analysis results

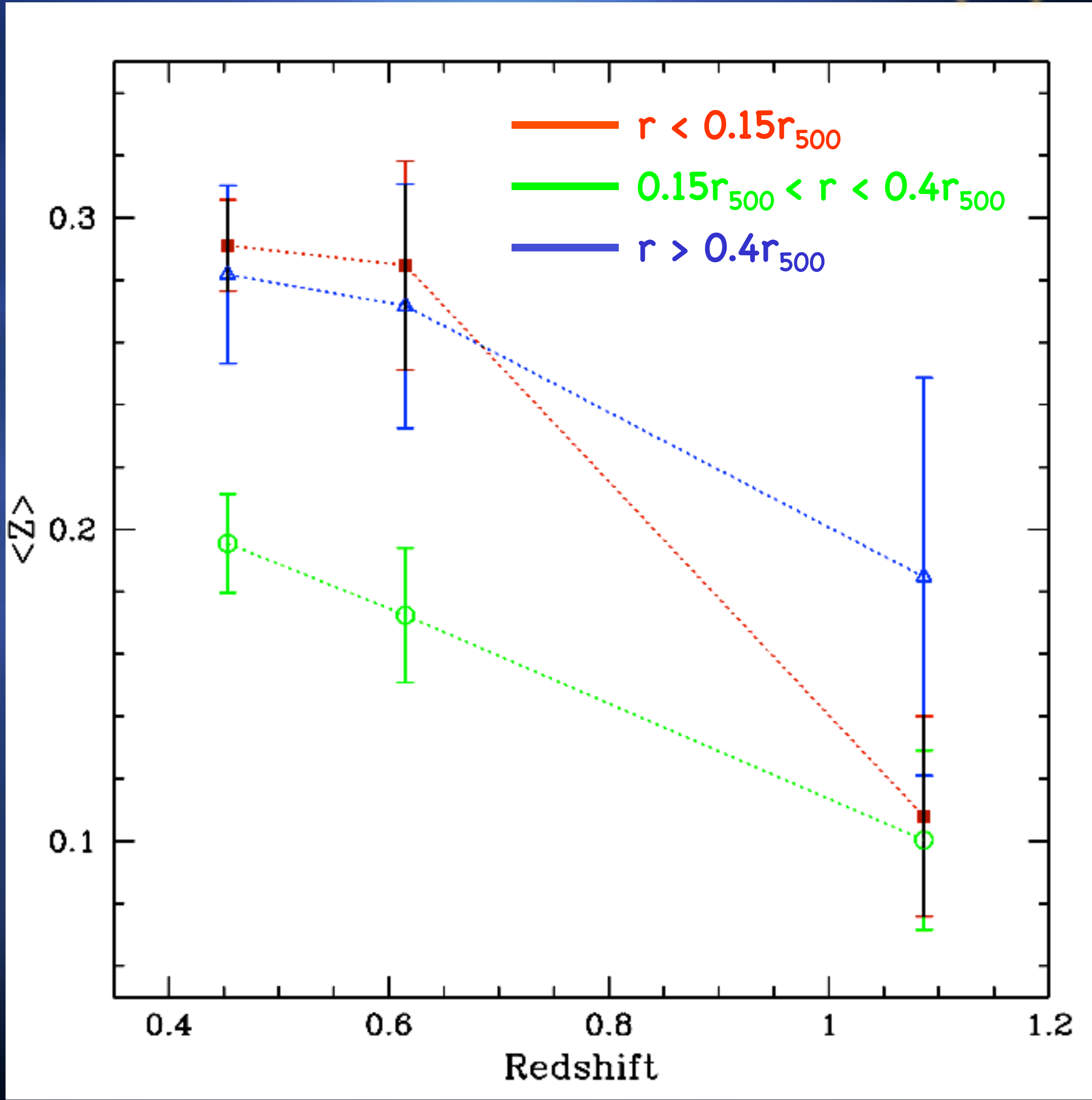
Baldi et al. 2010 in prep.

We averaged the abundance in 3 different redshift bins:

- ✓ $0.4 < z < 0.5$
- ✓ $0.5 < z < 0.7$
- ✓ $0.7 < z < 1.4$

Abundance evolution can be observed in all three spatial bins:

- $Z \propto z^{-0.3}$ for $r < 0.15\ r_{500}$
- $Z \propto z^{-0.8}$ for $0.15\ r_{500} < r < 0.4\ r_{500}$
- $Z \propto z^{-0.5}$ for $r > 0.4\ r_{500}$

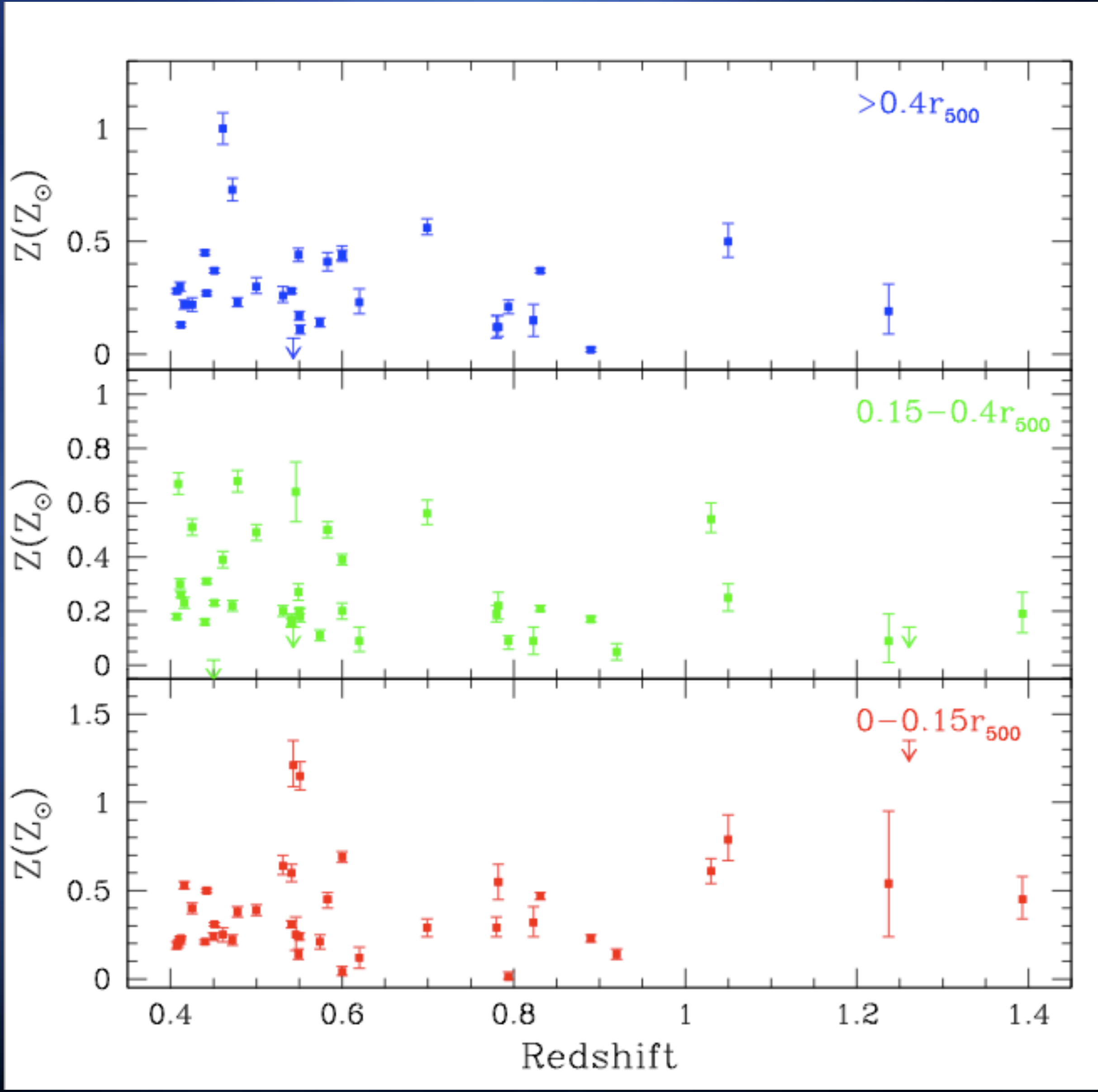


The IXO Perspective

- We performed simulations with different IXO instruments using the *SIMX* simulation tool.
- We found that most of the clusters in our XMM sample could not be observed by the XMS calorimeters farther than 0.6-0.7r_{500} → this would prevent us from exploring the outskirts of the clusters and from getting an accurate background estimate.
- The Wide Field Imager (WFI) represents the best compromise between spectral and spatial resolution and field of view.
- We performed 20ksec WFI spectral simulation for all the galaxy clusters in our sample with XSPEC

IXO spectral analysis results

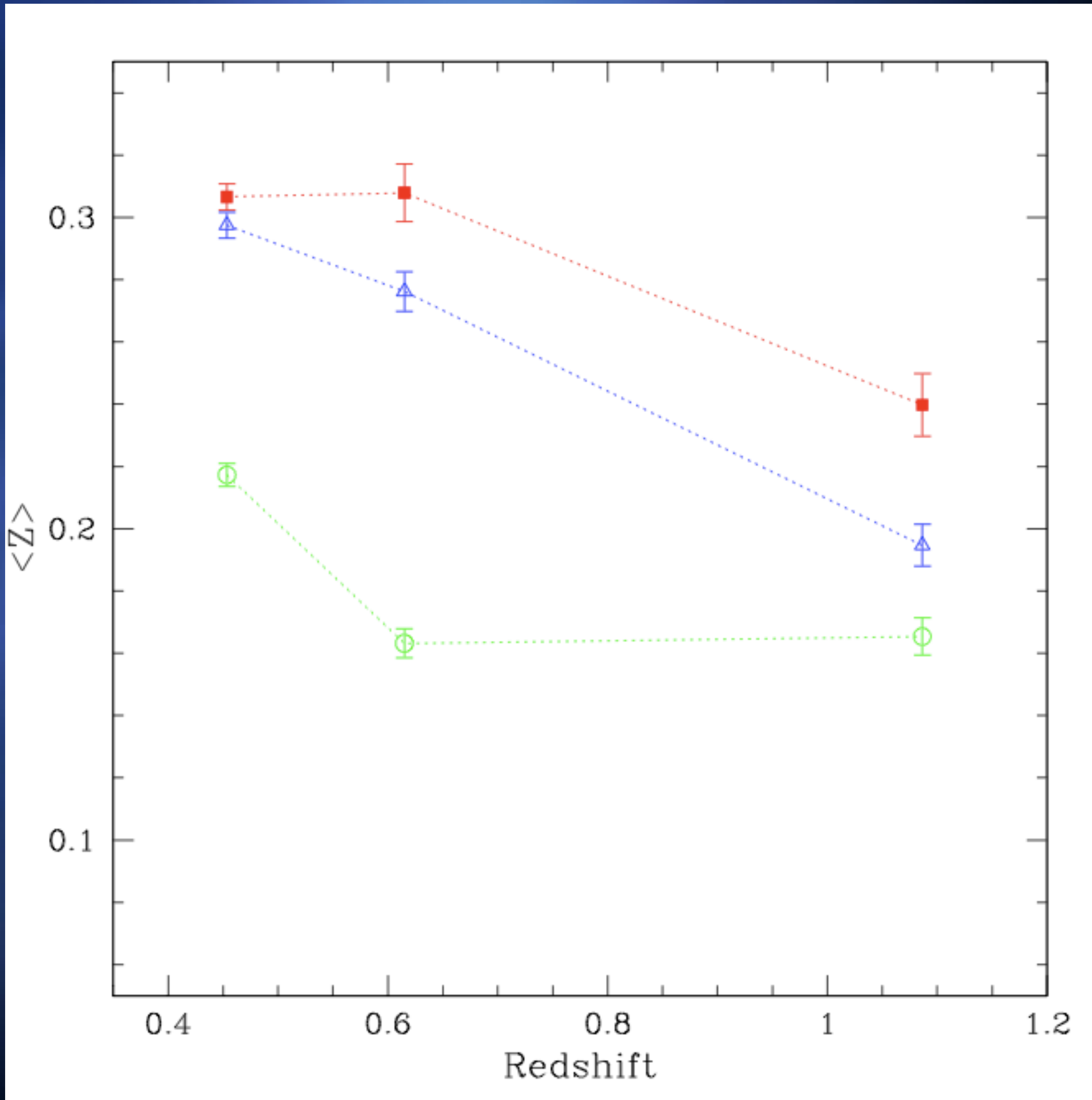
- Each simulated cluster spectrum (with the same spatial bins as in XMM analysis) was fitted with an XSPEC *mekal* model



IXO spectral analysis results

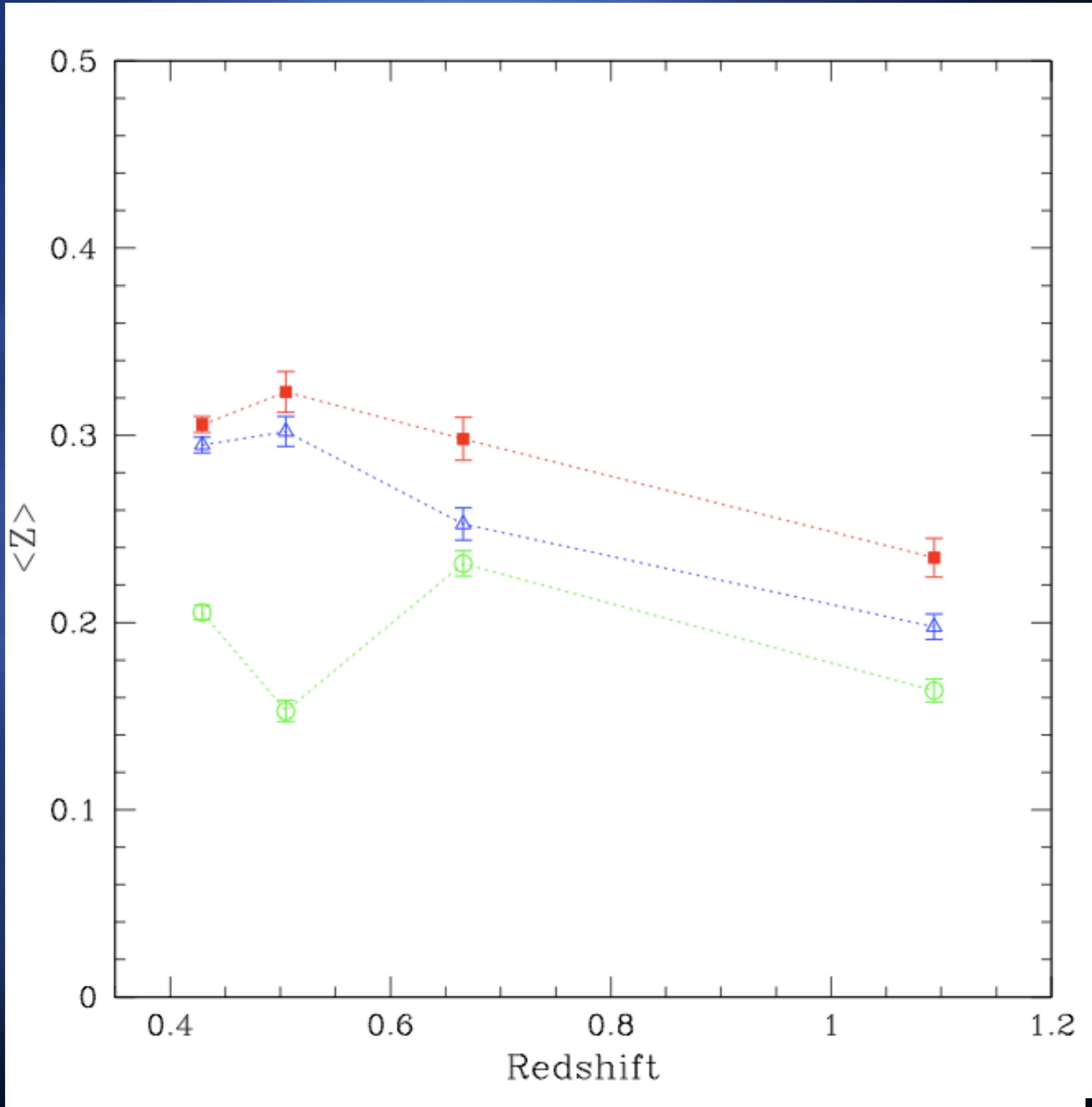
- We averaged the abundance in the same redshift bins used in the XMM analysis:
  - ✓ $0.4 < z < 0.5$
  - ✓ $0.5 < z < 0.7$
  - ✓ $0.7 < z < 1.4$

- The smaller errors would allow to determine with a high degree of confidence if an evolution in abundance in all 3 spatial regions is present.



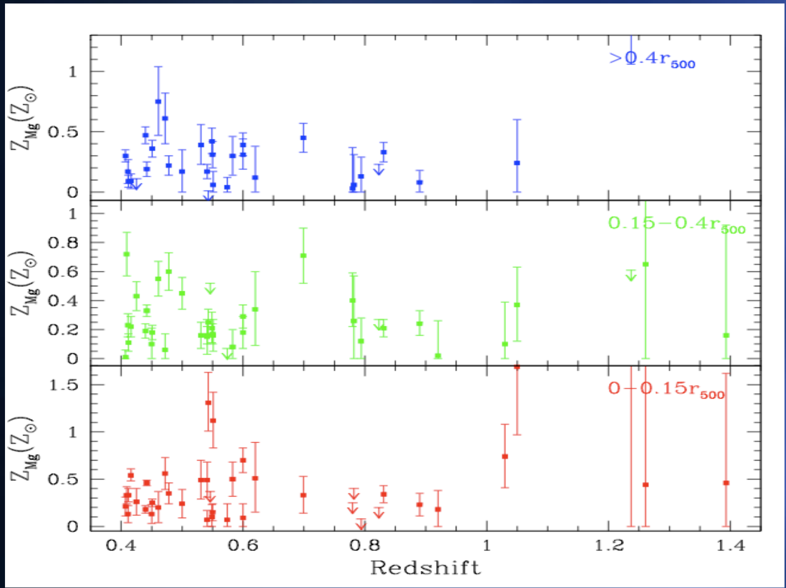
IXO spectral analysis results

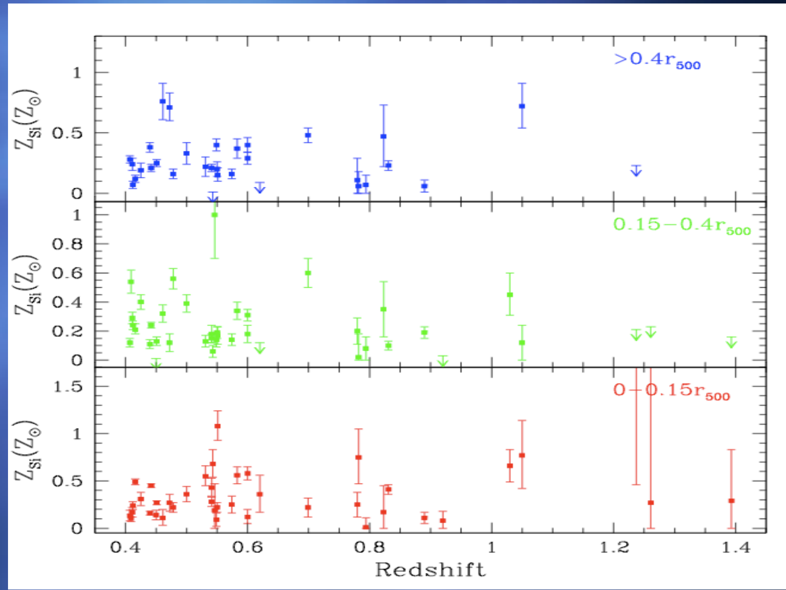
- We averaged the abundance in the same redshift bins used in the XMM analysis:
  - ✓ 0.4 < z < 0.5
  - ✓ 0.5 < z < 0.7
  - ✓ 0.7 < z < 1.4
- The smaller errors would allow to determine with a high degree of confidence if an evolution in abundance in all 3 spatial regions is present.
- A larger number of redshift bins could also be used.

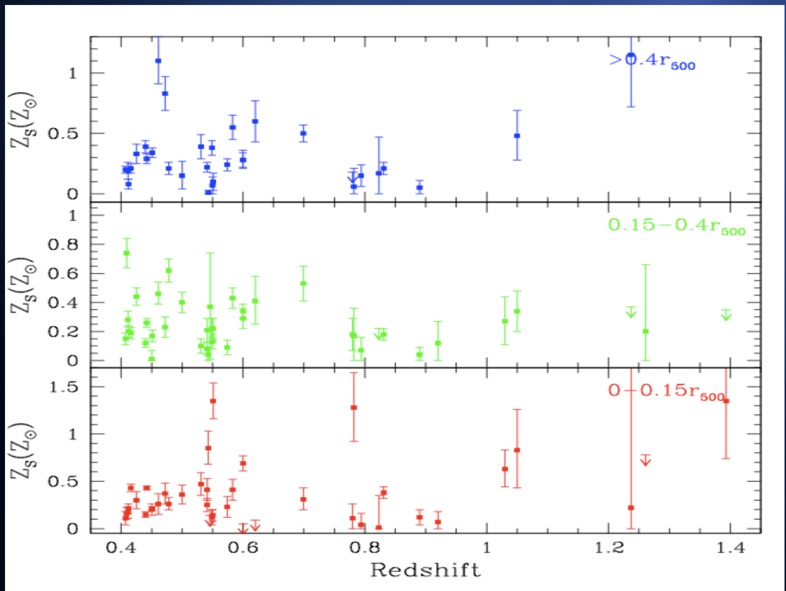


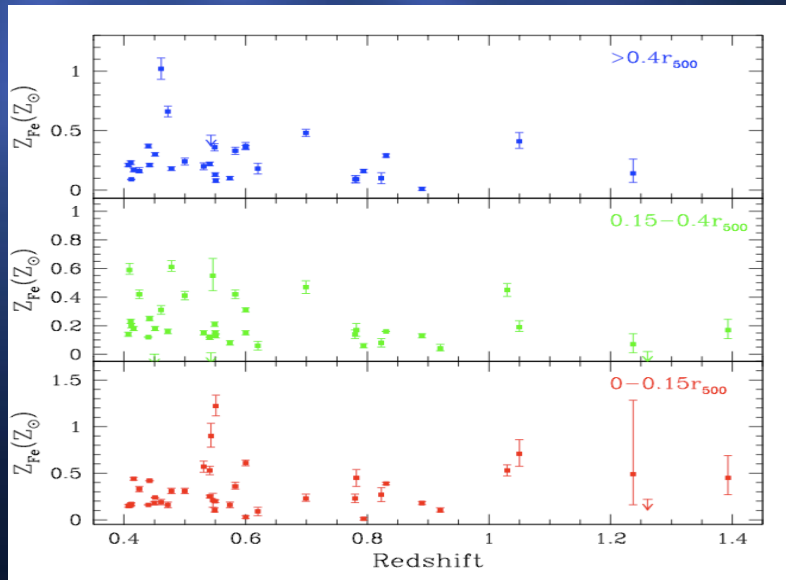
Individual elements abundance

- The high S/N WFI spectra would allow to investigate the evolution in abundance of the individual elements out to z≈1

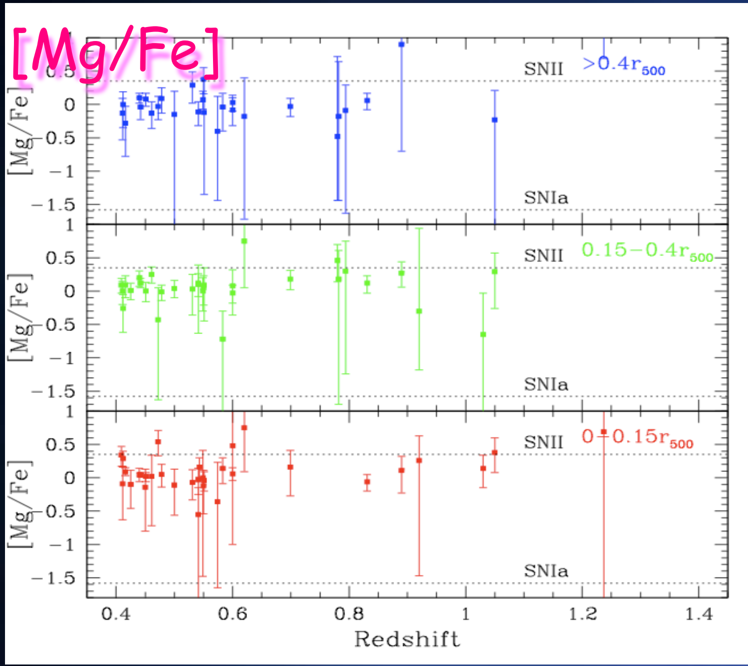


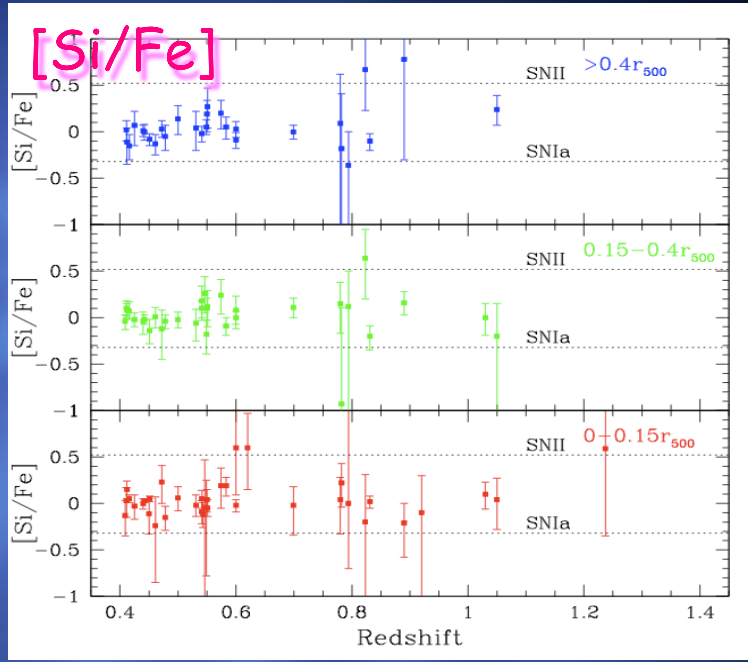


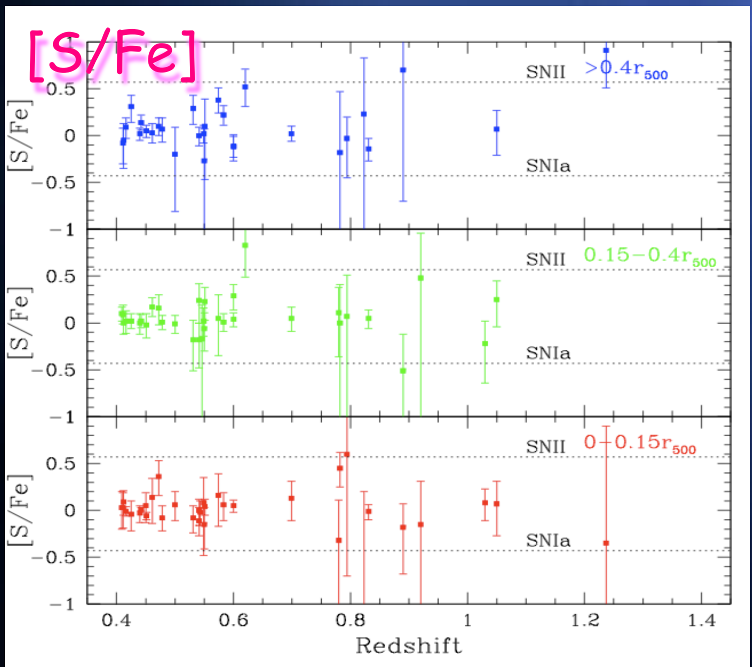




Abundance ratios and SN yields







- The abundance ratios between α elements and Fe would allow the comparison with the metal abundance yields expected from different SN types and therefore to study the history of ICM enrichment through SNIa and SNII.

Summary

- We presented a sample of 40 galaxy clusters at $0.4<z<1.4$ extracted from the XMM-Newton archive.

- A spatially resolved spectral analysis of the clusters in the sample revealed hints of an evolution in abundance not limited to the cluster cores, but involving also regions farther than 0.4 r_{500} from the center, extending the results of Balestra et al. (2007) and Maughan et al. (2008).

- IXO WFI spectral simulation of the clusters in the sample showed how the high count statistics expected could confirm (or deny) with a higher degree of confidence the presence of an evolution in abundance.

- Abundance of individual elements could also be measured with small statistical errors down to $z \approx 1$, allowing to trace the ICM enrichment history through SNIa and SNII.